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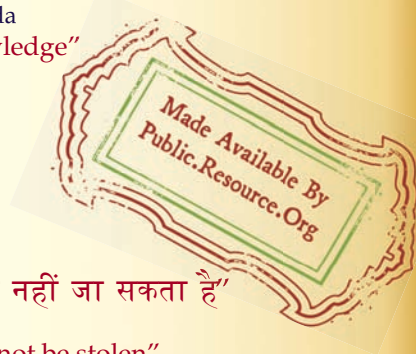
IS/IEC 61757-1 (1998): Fibre Optic Sensors, Part 1: Generic Specification [LITD 11: Fibre Optics, Fibers, Cables, and Devices]



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“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”

Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

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भारतीय मानक
प्रकाशिक तंतु सेंसर
भाग 1 वर्गीय विशिष्टि

Indian Standard
FIBRE OPTIC SENSORS
PART 1 GENERIC SPECIFICATION

ICS 33.180.10

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Price Group 9

Fibre Optics, Fibres, Cables and Devices Sectional Committee, LITD 11

NATIONAL FOREWORD

This Indian Standard (Part 1) which is identical with IEC 61757-1 : 1998 'Fibre optic sensors — Part 1: Generic specification' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Fibre Optics, Fibres, Cables and Devices Sectional Committee and approval of the Electronics and Information Technology Division Council.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

- a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.
- b) Comma (,) has been used as a decimal marker in the International Standard while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their places are listed below along with their degree of equivalence for the editions indicated:

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC 60027-1 (All parts) Letter symbols to be used in electrical technology	IS 3722 (All parts) Letter symbols and signs used in electrical technology	Technically Equivalent
IEC 60060-1 High-voltage test techniques — Part 1: General definitions and test requirements	IS 2071 (Part 1) : 1993 High voltage test techniques: Part 1 General definitions and test requirements (<i>second revision</i>)	do
IEC 60068-1 Environmental testing — Part 1: General and guidance	IS 9000 (Part 1) : 1988 Basic environmental testing procedures for electronic and electrical items: Part 1 General (<i>first revision</i>)	do
IEC 60068-2-1 Environmental testing — Part 2: Tests — Tests A: Cold	IS 9000 (Part 2/Sec 1 to 4) : 1977 Basic environmental testing procedures for electronic and electrical items: Part 2 Cold test	do
IEC 60068-2-2 Environmental testing — Part 2: Tests — Tests B: Dry heat	IS 9000 (Part 3/Sec 1 to 5) : 1977 Basic environmental testing procedures for electronic and electrical items: Part 3 Dry heat test	do
IEC 60068-2-3 Environmental testing — Part 2: Tests — Tests Ca: Damp heat, steady state	IS 9000 (Part 4) : 1979 Basic environmental testing procedures for electronic and electrical items: Part 4 Damp heat (steady state)	do

IS/IEC 61757-1 : 1998

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC 60068-2-6 Environmental testing — Part 2: Tests — Test Fc: Vibration (sinusoidal)	IS 9000 (Part 8) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 8 Vibration (sinusoidal) test	Technically Equivalent
IEC 60068-2-9 Environmental testing — Part 2: Tests — Guidance for solar radiation testing	IS 9001 (Part 11) : 1973 Guidance for environmental testing: Part 11 Solar radiation testing	do
IEC 60068-2-10 Environmental testing — Part 2: Tests — Test J and guidance: Mould growth	IS 9001 (Part 10) : 1975 Guidance for environmental testing: Part 10 Mould growth test	do
IEC 60068-2-11 Environmental testing — Part 2 : Tests — Test Ka: Salt mist	IS 9001 (Part 19) : 2006 Guidance for environmental testing: Part 19 Salt mist test	do
IEC 60068-2-14 Environmental testing — Part 2: Tests — Test N: Change of temperature	IS 9001 (Part 3) : 1978 Guidance for environmental testing: Part 3 Change of temperature	do
IEC 60068-2-27 Environmental testing — Part 2: Tests — Test Ea and guidance: Shock	IS 9001 (Part 17/Sec 1) : 2000 Guidance for environmental testing: Part 17 Impact test, Section 1 Shock test (Test Ea) (<i>first revision</i>)	do
IEC 60068-2-29 Environmental testing — Part 2: Tests — Test Eb and guidance: Bump	IS 9002 (Part 7) : 1983 Specification for equipment for environmental tests for electronic and electrical items: Part 7 Bump test machine	do
IEC 60068-2-42 Environmental testing — Part 2: Tests — Tests Kc: Sulphur dioxide test for contacts and connections	IS 9000 (Part 26) : 1980 Basic environmental testing procedures for electronic and electrical items: Part 26 Sulphur dioxide test for contacts and connections	do
IEC 60068-2-43 Environmental testing — Part 2: Tests — Test Kd: Hydrogen sulphide test for contacts and connections	IS 9000 (Part 25) : 1980 Basic environmental testing procedures for electronic and electrical items: Part 25 Hydrogen sulphide test for contacts and connections	do
IEC 60143 Series capacitors for power systems	IS 9835 : 1981 Series capacitors for power systems (<i>first revision</i>)	do
IEC 60617-1 (All parts) Graphical symbols for diagrams	IS 2032 (All parts) Graphical symbols used in electrotechnology	do
IEC 60695-2-2 Fire hazard testing — Part 2: Test methods — Section 2: Needle-flame test	IS 11000 (Part 2/Sec 1) : 1984 Fire hazard testing: Part 2 Test methods, Section 1 Glow-wire test and guidance	do

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC 60794-1 Optical fibre cables — Part 1: Generic specification	IS 13882 (Part 1/Sec 1) : 2001 Optical fibre cables: Part 1 General specification, Section 1 General	Technically Equivalent
IEC 60874-1 Connectors for optical fibres and cables — Part 1: Generic specification	IS QC 210000 : 1994 Connectors for optical fibres and cables generic specification	do
IEC 61000-4-2 Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 2: Electrostatic discharge immunity test	IS 14700 (Part 4/Sec 2) : 2008 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Section 2 Electrostatic discharge immunity test	do
IEC 61000-4-3 Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 3: Radiated, audio-frequency, electromagnetic field immunity test	IS 14700 (Part 4/Sec 3) : 2008 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Section 3 Radiated, radio-frequency, electromagnetic field immunity test	do
IEC 61000-4-4 Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 4: Electrical fast transient/burst immunity test : Basic EMC publication	IS 14700 (Part 4/Sec 4) : 2008 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Section 4 Electrical fast transient/burst immunity test	do
IEC QC 001001 Basic rules of the IEC quality assessment system for electronic components (IECQ)	IS QC 001001 : 2000 IEC Quality assessment system for electronic components (IECQ) — Basic rules (<i>first revision</i>)	do
IEC QC 001002 (All parts) IEC quality assessment system for electronic components (IECQ) — Rules of procedure	IS QC 001002 (All parts) Rules of procedure of the IEC quality assessment system for electronic components (IECQ)	do
ISO 129 Technical drawings — Dimensioning — General principles, definitions, methods of execution and special indications	IS 11669 : 1986 General principles of dimensioning on technical drawings	do
ISO 286-1 ISO system of limits and fits — Part 1: Bases of tolerances, deviations and fit	IS 919 (Part 1) : 1993 Systems of limits and fits: Part 1 Bases of tolerances, deviations and fits (<i>second revision</i>)	do
ISO 370 Toleranced dimensions — Conversion from inches into millimetres and <i>vice versa</i>	IS 1105 : 1957 Method for precise conversion of inch and metric dimensions to ensure interchangeability	do
ISO 1101 Technical drawings — Geometrical tolerancing — Tolerances of form orientation, location and run-out — Generalities, definitions, symbols, indications on drawings	IS 8000 (Part 1) : 1985 Geometrical tolerancing on technical drawings: Part 1 Tolerances of form orientation, location and run-out and appropriate geometrical definitions (<i>first revision</i>)	do

IS/IEC 61757-1 : 1998

The technical committee has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

<i>International Standard</i>	<i>Title</i>
IEC 60068-2-5	Environmental testing — Part 2: Tests — Test Sa: Simulated solar radiation at ground level
IEC 60068-2-13	Environmental testing — Part 2: Tests — Test M: Low air pressure
IEC 60255-3	Electrical relays — Part 3: Single input energizing quantity measuring relays with dependent or independent time
IEC 60825-1	Safety of laser products — Part 1: Equipment classification, requirements and user's guide
IEC 61000-4-5	Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 5 : Surge immunity test

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard, and as such the page numbers are not the same as in the IEC Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard
FIBRE OPTIC SENSORS
PART 1 GENERIC SPECIFICATION

1 Scope

This part of IEC 61757 is a generic specification covering optical fibres, components and sub-assemblies as they pertain specifically to sensing applications, in those aspects not already addressed by previous or concurrent standardization efforts.

A fibre optic sensor contains an optical or optically powered sensing element in which the information is created by reaction of light to a measurand. The sensing element can be the fibre itself or an optically powered element inserted along the optical path. In a fibre optic sensor, one or more light parameters are directly or indirectly modified by the measurand somewhere in the optical path, contrary to an optical data link where the information is merely transmitted from the transmitter to the receiver.

The object of this generic specification is to define, classify and provide the framework for specifying fibre optic sensors, and their specific components and subassemblies. Fibre optic sensors are devices for extracting information from the environment using fibre optic technology.

2 Normative references

The following normative documents contain provisions, which, through reference in this text, constitute provisions of this part of IEC 61757. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 61757 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60027-1 (all parts), *Letter symbols to be used in electrical technology*

IEC 60060-1,— *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60068-1, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-1, *Environmental testing – Part 2: Tests – Tests A: Cold*

IEC 60068-2-2, *Environmental testing – Part 2: Tests – Tests B: Dry heat*

IEC 60068-2-3, *Environmental testing – Part 2: Tests – Test Ca: Damp heat, steady state*

IEC 60068-2-5, *Environmental testing – Part 2: Tests – Test Sa: Simulated solar radiation at ground level*

IEC 60068-2-6, *Environmental testing – Part 2: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-9, *Environmental testing – Part 2: Tests – Guidance for solar radiation testing*

IEC 60068-2-10, *Environmental testing – Part 2: Tests – Test J and guidance: Mould growth*

IEC 60068-2-11, *Environmental testing – Part 2: Tests – Test Ka: Salt mist*

IEC 60068-2-13, *Environmental testing – Part 2: Tests – Test M: Low air pressure*

IEC 60068-2-14, *Environmental testing – Part 2: Tests – Test N: Change of temperature*

IEC 60068-2-27, *Environmental testing – Part 2: Tests – Test Ea and guidance: Shock*

IEC 60068-2-29, *Environmental testing – Part 2: Tests – Test Eb and guidance: Bump*

IEC 60068-2-42, *Environmental testing – Part 2: Tests – Test Kc: Sulphur dioxide test for contacts and connections*

IEC 60068-2-43, *Environmental testing – Part 2: Tests – Test Kd: Hydrogen sulphide test for contacts and connections*

IEC 600143, *Series capacitors for power systems*

IEC 60255-3, *Electrical relays – Part 3: Single input energizing quantity measuring relays with dependent or independent time*

IEC 60617-1 (all parts), *Graphical symbols for diagrams*

IEC 60695-2-2, *Fire hazard testing – Part 2: Test methods – Section 2: Needle-flame test*

IEC 60794-1, *Optical fibre cables – Part 1: Generic specification*

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification, requirements and user's guide*

IEC 60874-1, *Connectors for optical fibres and cables – Part 1: Generic specification*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 2: Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 3: Radiated, audio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test. Basic EMC publication*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 5: Surge immunity test*

IEC QC 001001, *Basic rules of the IEC Quality Assessment System for Electronic Components (IECQ)*

IEC QC 001002, *Rules of procedure of the IEC Quality Assessment System for Electronic Components (IECQ)*

ISO 129, *Technical drawings – Dimensioning – General principles, definitions, methods of execution and special indications*

ISO 286-1, *ISO system of limits and fits – Part 1: Bases of tolerances, deviations and fit*

ISO 370, *Toleranced dimensions – Conversion from inches into millimetres and vice versa*

ISO 1101, *Technical drawings – Geometrical tolerancing – Tolerances of form, orientation, location and run-out – Generalities, definitions, symbols, indications on drawings*

3 Definitions

For the purpose of this part of IEC 61757, the following definitions apply:

3.1

fibre optic sensor

sensor relying on the optical characteristics of optical fibre(s) to extract or relay environmental information for control or measurement purposes. It includes an optical or optically powered sensing element and may include one or more of the following (see figures 1 and 2):

- optical fibre lead;
- signal conditioning

3.2

intrinsic fibre optic sensor

fibre optic sensor whose sensing element consists of one or more optical fibre(s) in which one or more of the propagation, reflection or light emission characteristics depend on the measurand

3.3

extrinsic fibre optic sensor

fibre optic sensor in which the characteristics of the light are affected externally to the optical fibre(s) by the measurand

3.4

optical or optically powered sensing element

device which accepts information in the form of a physical quantity and converts it to information in the form of an optical quantity, according to a definite law

3.5

single-point fibre optic sensor

fibre optic sensor which provides a measurement of a measurand by means of a discrete sensing element

3.6

multiple-point fibre optic sensor

fibre optic sensor which includes a number of multiplexed single-point sensors

3.7

extended fibre optic sensor

fibre optic sensor which provides a measurement of a measurand over an extended region by means of a continuous sensing element

3.8

distributed fibre optic sensor

fibre optic sensor which provides a spatially resolved measurement of a measurand over an extended region by means of a continuous sensing element

3.9

optical source

device which supplies the optical energy required to allow the interaction between the sensing element and the measurand. It contains, as a minimum, a luminous source and it may contain signal conditioning. When the optical energy is generated by the phenomenon sensed, no optical source is required

3.10

optical receiver

device which receives the light affected by the measurand and converts it into a quantity, generally electric, according to a predetermined law. It may contain one or more photo-detectors, signal conditioners and communication interfaces

3.11

optical fibre lead(s)

optical fibre line(s) which connect the sensing element to the optical source and to the optical receiver.

When present, these leads must remain unaffected by the measurand

3.12

optical interface

arbitrary point at which the effect of the measurand on the sensing element is optically defined

3.13

signal interface

arbitrary point at which the effect of the measurand is present in a form directly usable for control or measurement purposes. The optical interface(s) and the signal interface(s) can in some cases coincide

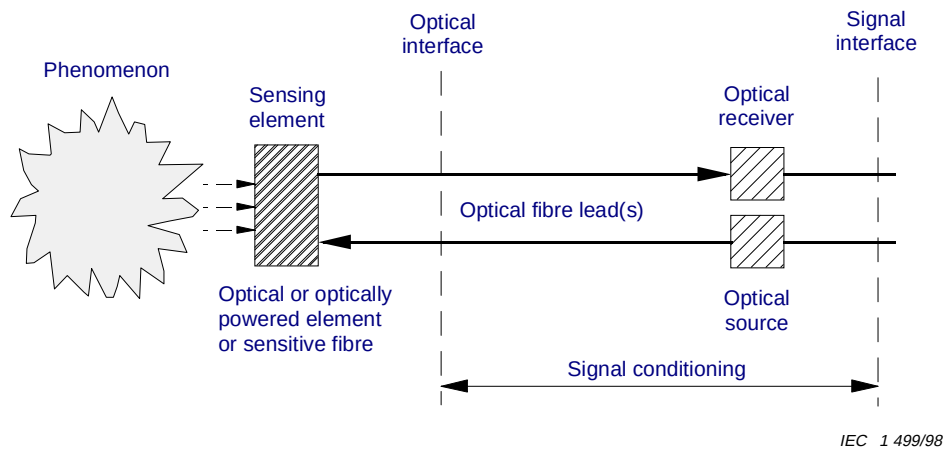


Figure 1

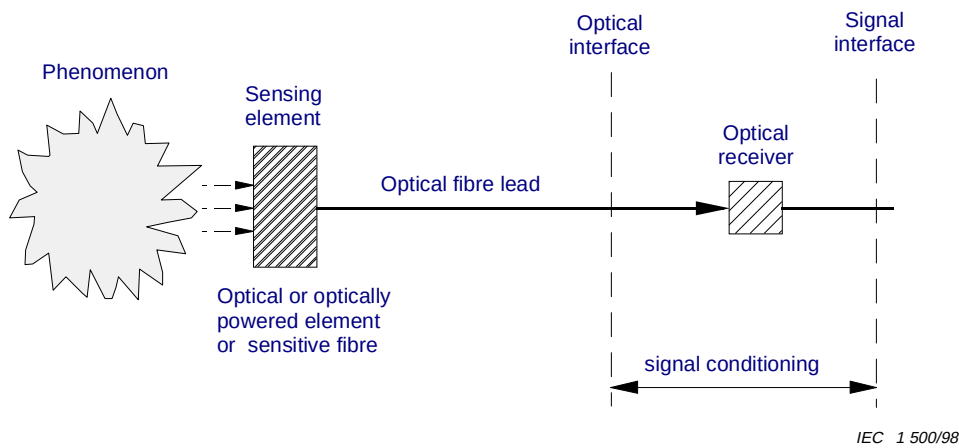


Figure 2

4 Units and symbols, dimensions

4.1 Units and symbols

Units and graphical symbols should, whenever possible, be taken from IEC 60027 and IEC 60617.

4.2 Dimensions

4.2.1 Details in sectional and detail specifications

Detail specifications shall provide information on maximum dimensions and tolerances on operating parameters such as optical power, electrical signal levels or electrical power requirements at the appropriate interface, to allow the user to design the sensor into the equipment or system.

Dimensions and variations in drawings shall be given in accordance with the relevant ISO publications, for example ISO 129, ISO 286-1 or ISO 1101.

Permissible variations shall be stated where necessary; basic values without tolerances, or simple maxima or minima shall be given where sufficient.

4.2.2 Dimensional units in the detail specification

The dimensions and deviations may be given in both millimetres and inches. The original system of units shall be stated.

Independently of the system of units, the highest accuracy required by the dimensions shall be such that the values, the first significant digit of which is 1 or 2, shall not comprise more than five digits. Those having the first significant digit between 3 and 9 shall not have more than four digits.

4.2.3 Conversion of inch dimensions into millimetres and vice versa

Where mechanical and optical considerations permit, in the conversion of dimensions, values shall be rounded to the nearest 0,01 mm or 0,0005 in. This also holds good for the conversion between the systems of units after the exact calculation according to ISO 370 has been made.

4.2.4 Note in detail specifications concerning conversion for toleranced inch dimensions into millimetres and vice versa

A note shall be added in each detail specification reading: "The value for dimensions in..*.. are derived from those in..*.. but are not necessarily exact according to ISO 370. They are, however, to be considered as acceptable alternatives to the original values with regard to accuracy."

5 Quality assessment procedures

The present generic specification provides the normative references, definitions, test and measurement procedures, and classification criteria applicable to fibre optic sensors in general. Because of the wide variety of fibre optic sensor classes, the sectional specifications shall prescribe those tests which are applicable to each particular class of fibre optic sensors. The sectional specifications shall also prescribe the other quality assessment procedures applicable to each particular class of fibre optic sensor in agreement with IEC QC 001001 and IEC QC 001002. The detail specifications shall describe which of the tests prescribed in the relevant sectional specifications are applicable to a particular style or variant of a fibre optic sensor.

The relevant sectional and/or detail specifications shall also specify which of the tests and performance levels are applicable to the different elements of the fibre optic sensor, such as the optical source, the optical receiver, the sensing element and the optical fibre leads.

Manufacturers of fibre optic sensors are responsible to insure that discrete components used in the construction of the sensor are within the applicable specifications of the IEC Quality Assessment System for Electronic Components (IECQ).

The omission of a particular test parameter does not absolve the manufacturer from final responsibility for the safety of the equipment, or for the proper design of the equipment to ensure proper functioning in the intended environment.

6 Test and measurement procedures

6.1 General

The purpose of this clause is to describe the general test and measuring methods applicable to fibre optic sensors. This clause specifies the tests which are covered by IECQ system. These tests are intended to address the interaction of the various components of the fibre optic sensor as they function to translate the specified measurand to the specified output at the optical or signal interface.

6.2 Standard conditions for testing

All discrete components (optical source, optical detector, optical fibre couplers, optical fibres, etc.) shall be tested in accordance with applicable specifications prior to assembly of the sensor. All components shall then be assembled and packaged in accordance with the detail specifications and instructions for use prior to testing the sensor in accordance with this specification.

Test and measurement equipment, including required power supplies and the source of the measurand (tunable within the range specified in the detail specification), shall be calibrated against standards traceable to international standards of measure. The stability of the test and measurement equipment shall be substantially better than the specified accuracy of the sensor.

Tests shall be carried out under standard atmospheric conditions for testing as specified in IEC 60068-1. Before measurements are made, the sensors shall be preconditioned under standard atmospheric conditions for testing, for a time sufficient to allow each element or the entire sensor to reach thermal stability. The above requirements shall apply, unless otherwise specified in the sectional and/or detail specifications.

When "mounting" is specified in a test, the specimen shall be securely mounted to a rigid support of suitable material, of dimensions and contour such that the specimen is rigidly and completely supported as it would be in use. For free or fixed specimens, the appropriate mounting fixtures shall be specified in the relevant sectional and/or detail specifications.

Recovery conditions for the interval following a conditioning test shall be in accordance with the relevant IEC publications unless otherwise specified in the sectional and/or detail specifications.

6.3 Visual inspection

The marking of each sensor shall be in accordance with clause 8 of this generic specification, and shall be inspected for legibility and completeness.

Visual inspection shall verify that all elements required in the detail specification are included in the sensor and connected as described in the detail specification to ensure proper functioning. Visual inspection shall also verify that no elements evidence any physical damage or imperfection that could impair the functioning or lifetime of the sensor.

6.4 Dimensions

Measurements shall be as specified in clause 4 of the present specification and in the relevant detail specification to ensure that the sensor conforms to all critical dimensions and weight as specified therein.

6.5 Metrological features

6.5.1 General

The purpose of the tests concerning metrological features is to verify the effect of the measurand on the sensor output at the optical or signal interface. This set of tests shall be carried out in accordance with the climatic and environmental tests specified in 6.9.

In this generic specification a basic measurement method will be outlined. Where it is expected that this method will require modifications to measure a particular coefficient, the modification or separate test will be described in the relevant sectional and/or detail specifications.

6.5.2 Relation between the measurand and the corresponding characteristics of the sensor output at the optical or the signal interface

During this test, the performance shall be measured as specified in the relevant sectional and/or detail specification.

When this test is required, the appropriate measurand values used shall be specified in the relevant sectional and/or detail specifications.

6.5.3 Measuring range

Under consideration.

6.5.4 Resolution

Under consideration.

6.5.5 Accuracy

Under consideration.

6.5.6 Response time

Under consideration.

6.5.7 Ranges of the measurand which guarantee the non-deterioration or the non-destruction of the sensing element

Under consideration.

6.6 Optical tests

6.6.1 General

In sensor configurations which permit optical testing, the following parameters may be included in the sectional and/or detail specifications.

6.6.2 Optical power

The optical power shall be measured with a duly calibrated optical power meter.

6.6.3 Nominal wavelength and appropriate spectral characteristics

Under consideration.

6.6.4 State of polarization

Under consideration.

6.6.5 Fibre connector performance

Under consideration.

6.7 Electrical tests

6.7.1 General

The purpose of electrical tests is to verify that the fibre optic sensor has been fabricated in accordance with safe and established design practices with regard to electrical equipment so that the fibre optic sensor can be operated safely and reliably. The following list of parameters may be used as a guide for determining which procedures are appropriate for those fibre optic sensors which include electrical components or circuits.

6.7.2 Parameters and test procedures

<i>Parameter</i>	<i>Test procedure</i>
Insulation resistance	IEC 60060-1
Dielectric withstand at industrial frequency	IEC 60060-1
Lightning impulse	IEC 60060-1
Voltage stress	See 6.7.3
Influence of damped oscillatory wave	IEC 60255-3
Fast transients	IEC 61000-4-4
Impulse sparkover voltage	IEC 61000-4-5
Impulse discharge current	IEC 61000-4-5
Electrostatic discharge	IEC 61000-4-2
Electromagnetic field	IEC 61000-4-3

6.7.3 Voltage stress

– *Influence of the level of voltage supply:*

The equipment is subjected to variations of the voltage supply U between $U_{\min}$ and $U_{\max}$ as specified in the relevant detail specification.

– *Slow variation of voltage supply:*

The equipment installed according to the instructions given in the relevant detail specification is powered by its rated voltage. The level of the voltage is decreased from rated voltage to 0 V, then increased from 0 V to rated voltage, as specified in the relevant detail specification.

– *Influence of frequency:*

As required by the relevant detail specification.

– *Influence of a micro-cut of supply voltage:*

As required by the relevant detail specification.

– *Third harmonic:*

As required by the relevant detail specification.

6.8 Mechanical tests

6.8.1 General

The purpose of mechanical tests is to verify that the fibre optic sensor has been fabricated in accordance with safe and established design practices with regard to mechanical reliability. The following list of parameters may be used as a guide for determining which procedures are appropriate for fibre optic sensors.

6.8.2 Parameters and test procedures

<i>Parameters</i>	<i>Test procedure</i>
Vibration	IEC 60068-2-6
Bump	IEC 60068-2-29
Shock	IEC 60068-2-27
Bending of fibre leads	IEC 60874-1 and IEC 60794-1
Twisting of fibre leads	IEC 60874-1 and IEC 60794-1
Crushing of fibre leads	IEC 60794-1
Tensile strength of fibre leads	IEC 60874-1 and IEC 60794-1
Fibre connector	IEC 60874-1

6.9 Climatic and environmental tests

6.9.1 General

Climatic and environmental tests are designed to verify that the influence of the specified climatic and environmental conditions on the metrological features of the system are in accordance with the detail specification. During these tests, the value of the measurand shall be in accordance with the detail specification in magnitude and stability. The following list of parameters may be used as a guide for determining which procedures are appropriate for fibre optic sensors.

In common with other components the climatic category of a fibre optic sensor shall be expressed in the form prescribed in annex A of IEC 60068-1. The minimum test procedures for establishing the performance of a fibre optic sensor within a given climatic category are as follows:

- a) cold;
- b) dry heat;
- c) damp heat, steady state.

6.9.2 Parameters and test procedures

<i>Parameter</i>	<i>Test procedure</i>
Cold	IEC 60068-2-1 (Ab/Ad)
Dry heat	IEC 60068-2-2 (Bb/Bd)
Rapid change of temperature	IEC 60068-2-14 (Na/Nb)
Damp heat, steady state	IEC 60068-2-3
Damp heat, cyclic test	IEC 60068-2-30
Corrosive atmosphere	IEC 60068-2-11
Sealing	IEC 60143
Dust	IEC 60143
Industrial atmosphere	IEC 60068-2-42 and IEC 60068-2-43
Flammability	IEC 60695-2-2
Mould growth	IEC 60068-2-10
Low air pressure	IEC 60068-2-13
Solar radiation	IEC 60068-2-5 and 60068-2-9
Nuclear radiation	Under consideration
Susceptibility to ambient light	See 6.9.3

6.9.3 Susceptibility to ambient light

Measurement of susceptibility to ambient light is intended to establish that ambient light is not coupled to the optical fibres or to the optical receiver in a manner that adversely affects the fibre optic sensor performance. The wavelength, modulation, intensity and direction of a light source used to simulate ambient lighting shall be specified in the relevant sectional and/or detail specifications if applicable.

6.10 Resistance to solvents and contaminating fluids

A list of fluids to which the different elements of the fibre optic sensor shall be resistant shall be specified in the relevant sectional and/or detail specifications.

6.11 Long-term behaviour of the fibre optic sensor

This test is designed to verify the long-term stability of the metrological features of the sensor. Unless otherwise specified, the test shall be conducted at $75 \% \pm 5 \%$ of the maximum measurand value as specified in the relevant detail specification. The duration of the test shall be at least 1 000 h, unless otherwise specified in the relevant detail specification. Environmental conditions within the normal operating conditions shall be specified in the relevant detail specification. During and after the test, the metrological features of the sensor shall be in accordance with the values given in the relevant detail specification.

Other endurance tests, such as operation under maximum temperature and voltage, may be specified in the relevant sectional and/or detail specifications.

7 Classification

The purpose of this classification scheme is to allow for the development of sectional and detail specifications, based on the commonality of quality assurance procedures at the optical or the signal interface level.

For this purpose, fibre optic sensors are classified according to the following four types of criteria:

- measurand;
- transduction principle;
- spatial distribution;
- interface level.

7.1 Measurand

The measurand designates the physical or electrical quantity, property, or condition that is to be measured by the fibre optic sensor.

The following is not intended to be an all-inclusive list, but a sampling of measurands for fibre optic sensors. Examples given in annex A are illustrative and shall not be considered as limitative, nor do they constitute a recommendation or endorsement of a particular transduction principle.

7.1.1 Presence/absence of objects or features

7.1.1.1 *Limit sensor (button, lever, key):* A fibre optic limit sensor detects motion occurring beyond a predetermined point.

7.1.1.2 *Level:* A fibre optic level sensor detects when a solid or liquid rises or falls beyond a set position.

7.1.1.3 *Proximity:* A fibre optic proximity sensor detects the presence or absence of a given object.

7.1.1.4 *Photo-interruption:* A fibre optic photo-interruption sensor detects the crossing of a boundary by an object or a body.

7.1.2 Position

7.1.2.1 *Linear position:* A fibre optic linear position sensor determines the absolute or relative location of an object along a line within a certain bounded region.

A differential position sensor determines the relative position of two or more objects.

7.1.2.2 *Angular position:* A fibre optic angular position sensor determines the absolute or relative position of an object rotating about an axis.

7.1.2.3 *Proximity:* A fibre optic proximity sensor determines the relative closeness of an object to a predefined location.

7.1.2.4 *Zone (area):* A fibre optic zone sensor may be considered as a multi-dimensional extension of the linear position sensor. A two-dimensional array of sensing points or a converging/diverging set of sensor stimuli would constitute a zone sensor.

7.1.2.5 *Dimensional:* fibre optic dimensional sensors can be used to determine the dimensions of an object.

7.1.3 Rate of positional change

7.1.3.1 Linear speed or velocity: A fibre optic linear speed sensor determines the rate of movement of an object.

7.1.3.2 Rotational speed or velocity: A fibre optic rotational speed sensor determines the angular velocity of a rotating object.

7.1.3.3 Gyroscope: A fibre optic gyroscope is an inertial sensor which determines the rate of rotation or integrated degree of rotation with respect to a fixed inertial frame, defined about an input axis.

7.1.3.4 Linear acceleration: A fibre optic linear acceleration sensor determines the rate of change of the velocity of an object along a given vector.

7.1.3.5 Rotational acceleration: A fibre optic rotational acceleration sensor determines the rate of increase or decrease in angular velocity of a rotating object.

7.1.4 Flow

Fibre optic sensors can be used to determine the rate of flow or the amount of a moving fluid in a conduit, with several techniques in use.

7.1.5 Temperature

Fibre optic sensors can be used to determine temperature, with several techniques in use. Many thermal sensors are point sensors, but distributed sensors which measure multiple points on the same fibre, also exist.

7.1.6 Force x directional vector

7.1.6.1 Seismic: A fibre optic seismic sensor determines vibrational motion of the ground on a planet or other celestial object.

7.1.6.2 Vibration: A fibre optic vibration sensor determines the magnitude of force experienced by a body undergoing periodic motion in alternately opposite directions.

7.1.6.3 Torque: A fibre optic torque sensor determines the rotational force applied at a specific perpendicular distance to the axis of rotation of an object.

7.1.6.4 Weight: A fibre optic weight sensor determines the force of gravity acting on a body of a given mass.

7.1.7 Force per unit area

7.1.7.1 Acoustic: A fibre optic acoustic sensor determines the time-varying pressure caused by acoustic waves.

7.1.7.2 Pressure: A fibre optic pressure sensor determines the pressure of a gas or liquid.

7.1.8 Strain

Fibre optic sensors can be used to determine a finite change in the length of a material resulting from tension or compression, with several techniques in use.

7.1.9 Electromagnetic quantities

7.1.9.1 Magnetic field: A fibre optic magnetic field sensor determines magnetic fields, with several techniques in use.

7.1.9.2 Electrical current: A fibre optic current sensor is a special type of magnetic field sensor in which the integral of the magnetic field along some path around a conductor is measured. Because the integral of the magnetic field around a conductor is equal to the current flowing through the conductor (Ampere's law) the result is a sensor that responds only to the current in the conductor and not to other currents or magnetic fields in the vicinity.

7.1.9.3 Electric field: A fibre optic electric field sensor determines electric fields, with several techniques in use.

7.1.9.4 Voltage: A fibre optic voltage sensor is an electric field sensor in which electrodes are attached to the sensor in such a way that the electric field is applied to the sensing element in a defined geometry.

7.1.9.5 Electromagnetic radiation: Fibre optic sensors can be designed to detect or characterize electromagnetic radiation such as microwaves, light waves, etc.

7.1.10 Ionizing and nuclear radiation

This type of fibre optic sensors can be used to detect α , β , γ and other ionizing radiation.

7.1.11 Other physical properties of materials

7.1.11.1 Material refractive index: A fibre optic refractive index sensor determines refractive indices in mixtures of fluids.

7.1.11.2 Density: A fibre optic density sensor determines the mass density (g/cm^3) of particulate matter.

7.1.11.3 Viscosity: A fibre optic viscosity sensor determines the resistance to flow of a given fluid.

7.1.11.4 Damage: Gross structural damage, structural integrity and incipient damage of military hardware, civil engineering and architecture can be detected with fibre optic sensors.

7.1.12 Composition

7.1.12.1 Chemical: Fibre optic sensors can be used to examine a material or mixture. Qualitative and quantitative analyses for chemical species contaminants, and reaction process control are the main uses of this type of sensor.

7.1.13 Particulates

7.1.13.1 Count: A fibre optic particulate sensor determines the size distribution and frequency of airborne or liquid-borne particulate matter.

7.1.13.2 Atomic: Fibre optic sensors can be used to detect contaminated microscopic and macroscopic particulate matter that has become activated or otherwise radioactive.

7.1.13.3 Turbidity: A fibre optic turbidity sensor determines the cloudiness or opaqueness of a given fluid.

7.1.14 Imaging

A fibre optic image sensor can be used to transfer an image.

7.2 Transduction principle

The transduction principle describes the way in which the optical characteristics of light are affected by the measurand. It can be described by the transfer function from the measurand to the optical guided wave.

7.2.1 Active generation of light

The measurand directly creates optical energy, whose characteristics can be analyzed to extract an estimation of the measurand. Examples of active generation of light include blackbody radiation, Cerenkov radiation, electric arc.

7.2.2 Atom-field interaction

An optical probe at a specific wavelength or wavelengths is used to examine the desired measurand. The characteristics of the sensed material somehow modify the probe light, which is subsequently detected at one or more wavelengths or frequencies. Examples of atom-field interaction include spectrally resolved absorption, fluorescence, spectroscopy, Doppler and nonlinear effects.

7.2.3 Coherence modulation

Fibre optic sensors can use coherence modulation in conjunction with broadband light interferometric techniques to characterize measurands. Coherence modulation is often used to resolve a measurement spatially. Some white-light interferometers fall under this type of sensors.

7.2.4 Intensity modulation

Fibre optic sensors employing intensity modulation have a transfer function whose output is expressed as an intensity. Examples of intensity modulation include attenuation, coupling effects, interruption, microbending, reflectivity.

7.2.5 Optical spectrum modulation

Fibre optic sensors can use optical spectrum modulation. Examples of optical spectrum modulation include Brillouin scattering, fluorescence, broadband light interferometry, Doppler effect.

7.2.6 Phase modulation

Fibre optic sensors can use phase modulation in conjunction with interferometric techniques to characterize various measurands. Electro- or magneto-strictive coatings, acoustical energy, linear strain, Sagnac shift, Faraday effect and refractive index can all be used in phase-modulated sensors.

7.2.7 Polarization modulation

The state-of-polarization of optical energy can be modified by a measurand; rotation, and retardance are common phenomena. These mechanisms occur via the elasto-optic effect, optical activity or other transduction principles.

7.3 Spatial distribution

The spatial distribution describes the extension and resolution capabilities of the fibre optic sensor.

7.3.1 Single point

A single-point fibre optic sensor provides a measurement of a measurand by means of a discrete sensing element.

7.3.2 Multiple point

A multiple-point sensor includes a number of multiplexed single-point sensors.

7.3.3 Extended

An extended fibre optic sensor provides a measurement of a measurand over an extended region by means of a continuous sensing element. The measurand is not spatially resolved but is integrated or summed over the fibre length.

7.3.4 Distributed

A distributed fibre optic sensor provides a spatially resolved measurement of a measurand over an extended region by means of a continuous sensing element.

7.4 Interface level

The interface level is defined by the level of conditioning at which the output signal is available to the user. At this interface, both the sensor inputs and outputs shall be specified. Specifying these interfaces is necessary to enable the user to exploit the information provided by the sensor and to ensure interoperability between different products.

7.4.1 Optical interface

The optical interface applies to a fibre optic sensor which outputs the raw optical signal for subsequent processing by the user. Typical attributes for this type of interface would be the wavelength, state of polarization, optical power, and so on. More detailed specifications would include fibre-optic connector style, waveguide type, etc.

7.4.2 Signal interface

The signal interface applies to a fibre optic sensor which outputs signals in a form directly usable for control or measurement purposes, and which is generally electrical. Output schemes should preferably comply with existing interface standards such as those existing for electrical analogue signals or data communication protocols.

This typically describes a fibre optic sensor with a photodetector or other square-law detector, or with integrated signal processing electronics. Output schemes can be, for example, 4-20 mA, RS-485, etc.

8 Marking, labelling, packaging

8.1 Marking of component

Each fibre optic sensor shall be legibly and durably marked, where space permits, and in the following order of precedence, with:

- device identification;
- manufacturer's identity mark;
- manufacturing date code (year/week).

8.2 Marking of sealed package

Each sensor package shall be marked with the following:

- IEC type designation;
- any additional marking required by the sectional and/or detail specifications.

When required by the sectional and/or detail specifications, the package shall also include instructions for assembling the sensor(s) and the description of any special tools or materials, as necessary.

Where applicable, individual unit packages (within the sealed package) shall be marked with the reference number of the certified record of released lots, the manufacturer's factory identity code and the component identification.

9 IEC type designation

The fibre optic sensors to which this standard applies shall be designated by the letters IEC followed by the number of the relevant detail specification.

10 Safety aspects

Fibre optic components and systems may emit hazardous radiation. This can occur at:

- sources;
- transmission systems under the following conditions:
 - installation,
 - service or intentional interruption,
 - failure or unintentional interruption;
- measuring and testing.

10.1 Personal safety

For personal hazard evaluation, precautions and manufacturer's requirements, the relevant document is IEC 60825-1.

10.2 Intrinsic safety in flammable atmospheres

Under consideration.

11 Ordering information

The following ordering information shall be included in purchasing contracts for items complying with this standard:

- IEC type designation;
- any additional information or special requirements.

12 Drawings included in the sectional and detail specifications

The essential purpose of the drawings is to ensure mechanical interchangeability. They are not intended to restrict details of construction which do not affect interchangeability, nor are they to be used as manufacturing drawings. Equipment designers shall work to the limits stated and not to dimensions of individual specimens.

Annex A (informative)

Examples of fibre optic sensors

The examples given below illustrate how fibre optic sensors can measure the various measurands listed in 7.1. The classification in this annex closely follows that of 7.1. The examples given are illustrative and shall not be considered as limitative, nor do they constitute a recommendation or endorsement of a particular transduction principle.

A.1 Presence/absence of objects or features

A.1.1 Limit sensor (*button, lever, key*): A fibre optic limit sensor detects motion occurring beyond a predetermined point. The function of this device is typically to initiate a change of action when the predetermined point has been reached. An example of a fibre optic limit sensor is one which detects the breaking of a light beam, for example by a linear translation mechanism passing a reflective head. The limit sensor can then close (or open) a switch to stop the motion in order to avoid damaging the drive mechanism. This type of sensor is also useful for synchronization or home sensing for rotational or linear motion systems.

A.1.2 Level: A fibre optic level sensor detects when a solid or liquid rises or falls beyond a set position. For example, an optical fibre experiences a 4 % Fresnel reflection at the polished endface exposed to air, due to an index of refraction mismatch. When a liquid reaches this fibre end, the reflection decreases due to improved refractive index matching. The sensor can activate an alarm indicating that the liquid has risen or fallen, activate a valve to prevent damage or control processing.

A.1.3 Proximity: Fibre optic proximity sensors typically utilize reflection, infrared emission/reflection, or pressure principles to perform this detection without the necessity for direct physical contact. A typical fibre optic proximity sensor can be used under a carpet to detect the presence of people for security purposes. This sensor might, for example, employ microbending to respond to pressure or vibrational stimuli.

A.1.4 Photo-interruption: A photo-interruption sensor is a device emitting light which typically crosses a boundary such as a doorway. This beam of light is either detected at the opposite side of the boundary or reflected back to a detecting element on the emitting side. An object reflecting or interrupting the light will cause the photo-interruption sensor to trigger an alarm or relay. A fibre optic photo-interruption sensor may be used in applications such as safety mechanisms, counting, and access control.

A.2 Position

A.2.1 Linear position: Fibre optic linear position sensors may, for example, consist of an array of optical fibres placed in a parallel fashion. The object(s) to be detected would pass in front of this array and alter the transmission or reflection of light at the appropriate location from the ends of the fibres. The sensor processing electronics would then derive the proper position of the object within the sensing region from the relative optical amplitude of the signal from each of the fibres. The resolution of the detected position is dependent on the spacing of the sensing points.

A differential position sensor determines the relative position of two or more objects. Such a sensor may be used to help maintain the relative position of two moving objects. Fibre optic differential position sensors may consist of physically separated fibres utilizing reflective or transmissive techniques, or may employ interferometric techniques such as Fabry-Perot technique.

A.2.2 Angular position: A fibre optic angular position sensor can include multiple sensor fibres arranged in a radial fashion. One application would be the detection of the angular position of a gear or flywheel. A change in light intensity, as a reflective mark or transmissive slot passes a given sensing point, can be decoded to provide relative angular position. Again, the resolution is dependent on the spacing of the sensing points.

A.2.3 Proximity: A proximity sensor using fibre optic technology may have external constrictive coatings on an optical fibre which are acoustically sensitive. An impinging acoustical signal would change the optical signal amplitude in the fibre through a change in the amount of constriction on the fibre.

A.2.4 Zone (area): Fibre optic zone sensors may be arrays of sensors with sophisticated post processing to deal with the two-dimensional aspects. Phase detection techniques may also be utilized for zone type sensing.

A.2.5 Dimensional: The dimensions of an object may be sensed by using non-contacting fibre optic edge-detection techniques. On-line inspection systems, for example, need to determine the size of objects for sorting or quality purposes. The size of an object may be determined by utilizing an optical fibre array and sensing the change in reflectance or transmission of light in a particular region of the array.

A.3 Rate of positional change

A.3.1 Linear speed or velocity: Fibre optic sensors using Doppler phase shift methods are typical velocity sensors. Such sensors may detect the relative speed of an object without physical contact.

A.3.2 Rotational speed or velocity: A fibre optic rotational speed sensor typically provides an indication of the angular velocity of a rotating wheel, gear or shaft. The speed of rotation of an object may be indicated in revolutions per time period, or radians/degrees per time. A photo-interruption sensor, or chopper, may be utilized to detect the rotational speed or velocity of a given object. Rotational speed sensors are typically found in applications such as tachometers.

A.3.3 Gyroscope: A fibre optic gyroscope consists of a coil of optical fibre (may be polarization preserving) into which light is simultaneously propagating in clockwise and anticlockwise directions. The Sagnac effect, which is a relativistic phenomenon, induces a differential phase shift between clockwise and anticlockwise guided waves in the rotating media. The phase difference of the detected signals is compared and converted into a rate of rotation or an angle of rotation. There are several versions, such as the interferometric fibre optic gyroscope, resonant fibre optic gyroscope, Brillouin fibre optic gyroscope and guided-wave ring-laser gyroscope. Due to its small size and weight, a typical fibre optic gyroscope can be used in an aircraft or missile to replace a large, heavy, mechanical or ring-laser gyroscope.

A.3.4 Linear acceleration: Fibre optic accelerometers are normally interferometric in nature. Such sensors may detect acceleration in an indirect manner by taking advantage of the intrinsic strain characteristics of an appropriate optical fibre or a proof mass. Land vehicles and aircraft may utilize such sensors for performance measuring or safety systems.

A.3.5 Rotational acceleration: A typical fibre optic system would operate with phase differencing techniques. Fibre optic rotational acceleration sensors may be used where weight is a particular concern. Rotational acceleration sensing can be of use in applications such as anti-lock braking on vehicles to prevent skidding. A sudden change in the rate of deceleration can cause the sensor to initiate a correcting control action.

A.4 Flow

A fibre optic flow meter is a device that measures the rate of flow or the amount of a moving fluid in a conduit. The fibre optic flow meter can be identified by its applied theory: for example, velocity, force, vortex shedding, Doppler sensing of particulates. A fibre optic turbine meter would use a fibre to view turbine blade rotation for counting revolutions per minute (RPM). A fibre optic target meter would have a fibre end displaced by a fluid and the microbending of the fibre could be correlated to the fluid flow.

A.5 Temperature

Techniques include blackbody-absorbing, phosphorescent-coated, Raman scattering, Fabry-Perot cavity terminated or thermochromic-terminated optical fibres. These fibre optic sensors can trigger a switch at a set point or produce a continuous proportional output. One example of a fibre optic temperature sensor is the blackbody pyrometer. It consists of a blackbody emitting source which responds to incident temperature by emitting into the fibre an optical wavelength(s) of an intensity which is proportional to temperature.

A.6 Force x directional vector

A.6.1 Seismic: fibre optic seismic sensing may be done by detecting stress in a given fibre.

A.6.2 Vibration: The electrical isolation, noise immunity and small mass of fibre optic sensors make them well suited to detecting the degree of vibration present in a device or object. Fibre optic vibration sensors may utilize Doppler, intensity-based or phase-based detection schemes. Piezo-electric optical fibre coatings may be utilized in an intensity-based sensing scheme; another technique would involve a reflective proof mass forming part of a Fabry-Perot cavity.

A.6.3 Torque: A fibre optic torque sensor may utilize stress as the detecting scheme.

A.6.4 Weight: A change in attenuation due to microbend losses or change in absorption can be used to detect forces. Modal or spectral variations can also be used.

A.7 Force per unit area

A.7.1 Acoustic: Fibre optic acoustic sensors have been developed in recent years for use as hydrophones for underwater sound detection. These devices are based on fibre optic interferometers. Sound waves striking a coil of fibre in one of two parallel fibres of the interferometer will modulate the length of the sensing fibre slightly. This causes a modulated phase-shift of light in the sensing fibre relative to the reference fibre. The phase modulation can be detected by various heterodyne or homodyne techniques, allowing the sound waveform to be reconstructed.

A.7.2 Pressure: A typical fibre optic pressure sensor for measuring the pressure of a gas or liquid in a container might consist of a reflective diaphragm, one side of which is in contact with the fluid to be measured. An optical fibre (or a bundle of fibres) carries light to and from the diaphragm, which deflects or physically deforms when the pressure of the fluid changes. This deflection in turn changes reflection back into the return fibre lead to the optical receiver.

A physical pressure sensor might consist of a single optical fibre which is held between a pair of saw-toothed mechanical "jaws" at one or more positions along its length. A physical pressure applied to the jaws can mechanically bend the fibre enough to allow some microbending loss to occur, reducing the fibre transmission. This event is sensed by a decrease in the intensity of light at the receiver end of the optical fibre. Another method is to employ a polarimetric sensor via the elasto-optic effect. Such sensors might be used under a doormat as an intruder alarm. Another application might be a physical contact or grip pressure indicator for robot fingers.

A.8 Strain

A fibre optic strain sensor measures a finite change in the length of a material resulting from tension or compression. This type of sensor is typically based on microbend or polarimetric effects in a fibre. The output of these sensors is proportional to the amount of stress induced and may result in a phase (interferometric) or intensity variation. For example, an interferometric strain sensor could be embedded into the composite material skin of an aerospace vehicle in order to determine the extent of structural fatigue in the skin. The fatigue would be the result of stresses applied during flight.

A.9 Electromagnetic quantities

A.9.1 Magnetic field: Fibre optic sensors can be designed to measure magnetic fields using any of several effects. A direct mechanism is the Faraday effect, which is a magnetic field-induced circular birefringence, often described as a rotation of the plane of polarization of linearly polarized light. The Faraday effect can be exploited either in single-mode fibres or bulk materials. It is usually employed in a polarimetric configuration, though interferometric configurations can also be used.

An indirect, intrinsic approach to magnetic field sensors is the use of the magnetostrictive effect in a material attached to a single-mode fibre. Through the elasto-optic effect, the magnetically induced stress changes the propagation characteristics of the fibre which can be detected, usually interferometrically.

A.9.2 Electrical current: Fibre optic current sensors are usually based on the Faraday effect, either in single-mode fibre or bulk optics. An alternate technique uses the magnetostrictive effect; these sensors are interferometric (phase) or polarimetric in nature. Such sensors have advantages due to low mass, electrical isolation and lack of direct interconnection to the primary electrical conductor. A standard use for a fibre optic current sensor is to provide a safe means to monitor current levels in high-voltage power lines.

A.9.3 Electric field: There are no linear electro-optic effects in glass, only the quadratic (Kerr) effect, which is small, and, in principle, higher order effects. Fibre optic electric field sensors thus generally rely either on extrinsic or indirect intrinsic approaches. Extrinsic sensors are typically based on the Pockels effect in a crystalline material. The Pockels effect is an electric field-induced linear birefringence, which can be detected using either polarimetric or interferometric techniques. Sensors using the Pockels effect in both bulk and integrated optic configurations have been demonstrated.

An indirect, intrinsic electric field sensor can be designed using a piezo-electric effect to induce an electric field-dependent stress in an optical fibre. That stress causes a change in the propagation constant of the fibre which can be detected, usually interferometrically.

A.9.4 Voltage: In a sensor based upon the Pockels effect, the electrodes might be applied to the sides of the electro-optic crystal.

A.9.5 Electromagnetic radiation: A microwave radiation sensor can be designed by using a stress in an optical fibre induced by a temperature rise in a fibre coating sensitive to microwave radiation. Also fibre optic resonators or interferometers can be used to analyze the spectrum of light.

A.10 Ionizing and nuclear radiation

High-energy electromagnetic radiation can produce both loss and fluorescence in glass and other materials. The induced loss is usually associated with a particular type of defect known as a colour centre, which absorbs radiation in specific regions of the visible and near-infrared spectrum. To some degree, the loss is transient. In other cases, it is permanent, thus providing the possibility of total dose sensors.

One source of fluorescence is spontaneous emission from atomic and molecular energy levels excited by the incident radiation. Another source of light is Cerenkov radiation, which occurs when high energy photons scatter electrons within an optical material. If the velocity of these (Compton) electrons exceeds the phase velocity of light in the material, broadband radiation results. Scintillation fibre is an important class of Hadronic detectors for high-energy particle physics. Fluorescence sensors provide a means of measuring the dose rate (power) rather than dose (energy).

A.11 Other physical properties of materials

A.11.1 Material refractive index: A fibre optic refractive index sensor may consist of a miniature Fabry-Perot type interferometer inserted between two pieces of fibre, with fluid flowing through the optical cavity.

A.11.2 Density: The mass density of particulate matter may be determined by the amount of light transmitted or reflected in the measurement area. Fibre optic sensing of density may be performed using simple intensity-based techniques.

A.11.3 Viscosity: Viscosity is an indication of the resistance to flow of a given fluid. Shearing stress in the direction of fluid flow might be determined by taking advantage of the stress-dependent properties of optical fibre or more simply by detecting a change in the index of refraction or scattering in a fluid.

A.1.1.4 Damage: Excess loss can be induced in a damage-sensing fibre which is severed at some point along its length if a supporting member fails; optical time domain reflectometry may be used to locate the fault in the structure.

A.1.2 Composition

A.12.1 Chemical: Chemical presence/detection, concentration, identification, the cure monitoring of adhesives are some of the many applications for chemical sensors. A simple example of a chemical sensor might be a length of optical fibre having a coating over one end which contains a fluorescent material. The fluorescence could be excited by light transmitted down the fibre or by light from an external source. Some of the emitted fluorescence will be trapped in the fibre and guided back to a detector at the other end of the fibre. If the fluorescence of the material is stopped or quenched by, say, a change in the acidity of the surrounding solution (as measured by the concentration of H⁺ ions, expressed as the pH), then this device will function as a pH indicator or sensor.

Other fibre optic chemical sensors may use optical fibres merely as a convenient “light pipe” to carry light from a sample to an optical spectrometer for analysis. More advanced types use surface plasmon-polariton phenomena to evaluate composition at a metal dielectric interface, which is excited by a coupled guided wave. Combustion analysis, toxic gas sensing, relative humidity, environmental, agricultural and biosensors are additional fields of interest for fibre optic chemical sensors.

A.13 Particulates

A.13.1 Count: This can be done by simple interruption, scattering and other techniques.

A.13.2 Atomic: A combination of the fibre optic sensors mentioned in A.12.1 and A.9.5 may be used.

A.13.3 Turbidity: Turbidity may be detected by reflectance sensing techniques. The intensity of light reflected in an optical fibre based sensor system is changed as the level of turbidity in a fluid increases.

A.14 Spatial distribution

A.14.1 Single point: A liquid level sensor which couples light from one fibre to another when the sensor is in contact with air; an electric field sensor which uses polarization state change in a Pockels cell, etc.

A.14.2 Multiple point: A temperature sensor based on temperature-dependent absorption of neodymium-doped short fibre sections spliced at different places along a transmitting fibre, interrogated by optical time domain reflectometry, etc.

A.14.3 Extended: A Mach-Zehnder acoustic pressure sensor that integrates a pressure-caused phase shift along a several metres long fibre line; a damage-sensing fibre which is severed at some point along its length causing transmission to drop, if a supporting structural member fails, etc.

A.14.4 Distributed: A pressure sensor measuring microbend-induced losses continuously along a length of fibre, combined with an optical time domain reflectometer read-out; a temperature sensor using the ratio of Stokes to anti-Stokes scattered light continuously along a fibre, combined with an optical time domain reflectometer read-out, etc.

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